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AIRLIFT
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THE CASE FOR THE C-17

An Air Force Perspective

1991

EXECUTIVE SUMMARY

The United States Air Force is convinced of the vital importance of airlift to future U.S. national security—and of the essential need for the C-17 to preserve and enhance airlift capability. Airlift is a national asset in peacetime, in crisis, and in war.

In the wake of recent dramatic international developments, the Air Force has reassessed its role in the evolving security environment. While the probability of global war with the Soviet Union has diminished considerably, the easing of Cold War tensions does not equate to the emergence of a tranquil world. The future world will likely witness fast-brewing crises erupting in unpredictable locations—crises caused by well-armed individual states working their own agendas. While not all such crises will threaten vital U.S. interests, some—like the Iraqi invasion of Kuwait—certainly will. U.S. forces must be able to provide a rapid, tailored response wit a capability to intervene against a well-equipped foe, hit hard, and terminate quickly. The implication for U.S. forces is for fast, agile, modernized conventional capabilities.

Strategic mobility lies at the heart of a credible deterrent posture in such an environment—without the capability to project forces, there is no conventional deterrent. As forward forces decline, but global interests remain, lift will be even more in demand. To provide mobility for U.S. forces, the nation has historically relied on a balance of the complementary capabilities of the mobility triad: airlift, sealift, and prepositioning. Each has advantages and disadvantages—we capitalize on each method's virtues to compensate for the others' limitations. Airlift is an ideally suited mobility tool for an environment of uncertainty with widely dispersed potential flashpoints. As outlined in its strategic planning framework for the 1990s, *Global Reach—Global Power*, the Air Force identified supplying rapid global mobility as one of its critical objectives in supporting U.S. national security.

Exhaustive studies over the past decade have produced a single, consistent answer—the C-17 is the right airlift aircraft for the future. These studies call for an airlifter that can fly long ranges and carry outsize cargo, while providing the tactical performance and agility to open up more airfields for global operations. The most recent analysis was conducted at the request of Secretary of Defense Cheney. The study looked at a wide array of options in comparison to the C-17 program, including refurbishment of the C-141 force and procurement of other aircraft such as the C-5 or civil transports. Once again, the choice was clear. As Secretary of Defense Cheney testified to Congress, that analysis clearly showed: "The C-17 offered the most capability at least cost in every case."

The C-17 combines current technologies to create what is in many respects a revolutionary capability—a capability the Air Force calls "direct delivery." Cargo and personnel can be flown from the United States or elsewhere *directly* to where they are needed. In short, the C-17 combines the advantages of a strategic airlifter like the C-5—range, speed, aerial refueling, and payload (including outsize cargo)—with those of a tactical airlifter like the C-130—survivability, ability to operate on short, unimproved airfields, agility and maneuverability in the air and on the ground, and the ability to employ different methods of airdrop. The C-17 is highly flexible, designed to efficiently meet the nation's airlift needs across the entire range of potential scenarios.

This major increase in capability is provided by a set of interrelated technologies and design criteria incorporated in the C-17. These include: aircraft size; propulsive lift technology; and ground maneuverability. The C-17 features a wide, high cargo box in an aircraft with roughly the same external dimensions as a C-141. This results in an airframe that can carry the same types of cargo as a C-5, but in a much more compact vehicle—greatly easing the problems of operating a long-range airlifter into small airfields. The C-17's capabilities to operate into austere airfields are enhanced by the the use of powered lift, enabling the C-17 to approach runways at much lower speeds and steeper glide paths than conventional aircraft. It can thus land within very short distances with very heavy cargo loads—less than 3,000 feet with over 167,000 pounds of cargo. In essence, three times as many airfields worldwide are open to the C-17 as are available to the C-5 and C-141. In a recent example, during Operation Just Cause in Panama only two airfields could accommodate C-141s and C-5s. If the C-17 had been available, five airfields could have been employed. The C-17's exceptional ground maneuverability provides the capability to efficiently use limited ramp space. This capability is critical in theaters that contain numerous airfields with narrow taxiways and confined parking ramps. It allows the C-17 to deliver significantly more cargo than other airlifters.

Among other important performance advantages provided by the C-17 is enhanced survivability . The C-17's beefed up airframe has been designed to easily withstand the rugged military flight environment, and the aircraft features separated and redundant systems and self-inerting fuel tanks. The ability of the C-17 to employ a full range of aerial delivery techniques adds to its value. It will be able to airdrop paratroopers, equipment, and supplies; employ the Low Altitude Parachute Extraction System; and airdrop and extract outsize equipment—and do all of these precisely, over long ranges. It will be able to airdrop at night or in the weather. No aircraft comes close to matching those capabilities today.

A critical aspect of the C-17's design was life cycle cost—especially important in an era where aircraft service lives are projected to be many decades. The C-17 was designed from the outset to operate more efficiently and cost-effectively than any airlifter in the force. It will be able to deliver approximately double the cargo of a C-141B for approximately the same operating cost. This cost-effectiveness is, in part, the product of fuel efficiency—vital in light of increasing fuel costs. It also results from the advanced design, which will enable a crew of three to fly the C-17, and from significant improvements in reliability and maintainability, which produce substantial reductions in the number of maintenance man-hours per flying hour.

Historically, when the Department of Defense has put a new weapon system into the inventory, it has had no way to be sure that the system would achieve designed availability, reliability, and maintainability. The C-17 is the first major weapons system to offer a manufacturer's warranty guaranteeing that the American people will get what they've paid for. This first-of-a-kind warranty is one more reason that the C-17 is the nation's wisest possible investment in airlift capability.

Recent events in the Persian Gulf have provided dramatic emphasis as to why the nation needs robust and flexible airlift capabilities to support our national strategy. The United States Air Force is fully committed to the C-17 as the means to provide global reach to America's forces and put backbone into conventional deterrence for the 21st century.

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INTRODUCTION

August 8th, 1990...U.S. forces are boarding aircraft for rapid deployment to Saudi Arabia and the Persian Gulf in response to the Iraqi invasion of Kuwait. America is discovering once again the extraordinary value of airlift. It is an unusual quirk of military history that airlift is rarely fully appreciated except in crises, when it becomes a dominant focus of attention and concern. Yet paradoxically, airlift has become perhaps the nation's most frequently employed military tool, serving our interests in peacetime, crisis, and war.

As outlined in its strategic planning framework, *Global Reach—Global Power*, a key Air Force objective is to supply rapid global mobility. The United States Air Force is convinced of the vital importance of airlift to future U.S. national security—and of the essential need for the C-17 to preserve and enhance our airlift capability. This conviction is rooted in decades of experience and substantiated by thorough analyses of the capabilities needed to meet the demands of the evolving global security environment.

This paper lays out the case for the C-17. It first provides a historical perspective on the critical role our airlift forces have played in supporting U.S. national security. The paper then examines the evolving strategic environment and how airlift's role will become increasingly vital in meeting the demands of U.S. national strategy. The final sections then focus on the C-17 to demonstrate why this aircraft is the right airlifter for the future: these sections examine the evolution of the C-17 program in the context of changing U.S. national strategy and analyze the reasons for the aircraft's careful design and unique capabilities. This paper illustrates why a robust airlift capability will remain critical to U.S. national security—and why the C-17's unique capabilities make it the most efficient and cost-effective means of providing the multi-faceted contributions of the U.S. airlift force for the long-term.

A HISTORICAL PERSPECTIVE

As the debate over force requirements and appropriate levels of future defense spending was joined over the spring and summer, it was apparent that some did not have great appreciation for the importance of airlift in the context of overall U.S. national security policy. Some suggested that easing tensions in Europe eliminated the need for the C-17. Others stated that the C-17 wasn't the right airlifter—that a derivative of a commercial airliner would be cheaper and better. As this paper will show, these conclusions are erroneous. The C-17 is exactly the airlifter the nation needs to meet future security needs, and the requirement for it is greater than ever. But it should not be surprising that some require convincing. Underappreciation of airlift is as old as the emergence of modern airpower itself—and we, in the Air Force, have occasionally been guilty of it as well.

In the fall of 1941, a team of Army Air Corps officers led by Colonel Harold George worked feverishly to develop an air warfare plan in preparation for the increasingly likely event of war with the Axis powers. The estimated forces required were stunning—the planners envisioned vast air armadas of a size unimaginable just a few years earlier. In most cases, the recommended force levels proved remarkably prescient—for example, the planners predicted the number of heavy bombers required to prosecute allied strategy with great accuracy. But in one area, air transport—what we describe today as airlift—the planners' estimates proved woefully short. George's team estimated 2500 transports would be required. In reality, airlift proved so critical a resource to the allied war effort that in the closing days of World War II, over 10,000 transport aircraft were in service.

During the Second World War, airlift proved vital. It embodied airpower's attributes of speed, range, and flexibility. Seemingly insurmountable natural barriers—the mountains of Burma, the vast expanses of the Pacific and Atlantic Oceans, the deserts of North Africa—proved no obstacle to air vehicles. Commanders seized upon the rapid mobility provided by air transport to increase the effectiveness and flexibility of their forces. Air, land, and sea forces were deployed rapidly. Units cut off in the flow of battle were resupplied or withdrawn by air within hours. Vitally needed spares were moved in real time to restore the combat capabilities of air, land, and sea forces. And air transports carried paratroopers over defenses to assault enemy rear areas—as was done so effectively in the Normandy landings.

In the years following the war, succeeding generations of increasingly capable aircraft expanded the airlift envelope—and as the airlift fleet grew in capability, the mission grew in importance. Airlift had been a tool to serve national interests in combat; it emerged as a tool to strengthen security interests and achieve national objectives in peacetime as well.

Airlift and Combat Operations

Airlift provides U.S. policy with credible military muscle—it has been called "the backbone of deterrence." The presence of our airlift fleet deters adversaries because they know that U.S. forces can be deployed rapidly to deal with threats to U.S. security interests and those of our allies. With sufficient airlift, U.S. forces based in the CONUS can deter aggression in widely-spaced areas around the world—areas far too numerous to cover with forward based forces. And should deterrence fail, airlift enables our forces to be deployed and employed flexibly and efficiently.

The evolving and expanding capabilities of airlift have been demonstrated in each conflict that the United States has been engaged in since World War II. In the Korean War, airlift forces allowed the rapid deployment, redeployment, and supply of forces, which proved critical as front lines flowed up and down the peninsula.

The flexible potential of airlift forces in combat operations can be seen in one dramatic operation that took place in late 1950. Near the Chosin reservoir, six Chinese divisions had cut the escape routes for two Marine regiments and an Army regiment, raising the specter of annihilation. The only means of supplying these forces was by air. Airlift forces kept the units supplied with ammunition and food through airdrops until the Marines managed to hew a rough airstrip near their defensive positions, allowing airlifters to bring in supplies and evacuate wounded. In early December 1950, the airlift commander flew to the encircled Marine units to offer evacuation. The Marine commander asked instead that airlifters fly in personnel and equipment to reinforce existing forces and support a breakout. With the requested support, the Marine regiments fought their way out, managed to link up with the encircled Army regiment, and headed south. The North Koreans tried to block the planned escape route by destroying the sole bridge spanning a 1500 foot deep gorge. Airlifters responded by airdropping mobile bridge spans, enabling engineers to erect a bridge and the ground forces to withdraw successfully. Without airlift, these forces would have been destroyed and the U.S. dealt a considerable military and political defeat.

The U.S. experience in Korea demonstrated to the nation's political and military leaders the vital and flexible role that airlift could play in combat operations—it consequently played an even larger role in the Vietnam conflict. Capitalizing on the increased range, speed, and carrying capacity of the emerging long-range jet airlift force, units based in the continental United States were transported into theater within hours. For example, in the spring of 1972, a massive North Vietnamese offensive crashed through defending units near the demilitarized zone. In response, airlifters supported the rapid deployment of 164 American fighters and other essential war materials which were employed to break the momentum of the offensive. Vietnam also saw the maturation of theater airlift. Between 1965 and 1968 annual airlift operations within the theater increased tenfold to almost one million passengers and 250,000 tons of cargo per year. Units were able to exist and operate deep in hostile territory because of the airlift lifeline. Marine survival at the famous siege of Khe Sanh, as an example, was dependent on airlifted resupply. And throughout the conflict, wounded soldiers owed their lives to aeromedical evacuations by airlifters—in many of these cases, speed literally meant life.

In subsequent combat operations, airlift has been even more critical. In April-May 1965, civil disturbances in the Dominican Republic illustrated the importance of speed of response. Within a week, airlifters delivered 4544 troops and almost 7000 tons of cargo to help quell the disturbances and re-establish order.

In 1983's Grenada operation—Urgent Fury—military airlifters conducted combat airdrops, logistical resupply, evacuation of noncombatants, and aeromedical evacuation. In the first two weeks of the operation, MAC airlifters flew on average 70 missions a day to deliver over 15,000 tons of cargo and 36,000 troops and passengers.[1] American lives were protected in a very unstable situation and American interests were served. Speed was critical to success in this operation.

In the December 1989 Panama operation—Just Cause—airlift provided vital speed and flexibility. Although warning time for Just Cause extended over what might be described as months, reaction time was limited to hours. The speed and flexibility of airlift played a major role in enabling the joint force commander to execute a classic *coup de main*: to land decisive force quickly at night across Panama to throttle resistance in short order. Airlift built up forces just prior to the operation, airdropped an airborne brigade and a ranger regiment to spearhead it, and delivered reinforcements and supplies to sustain it. In less than 36 hours, 9,500 soldiers were airlifted to Panama—some in the largest night, combat airdrop since D-Day at Normandy. The joint force commander, General Thurman, testified to the importance of airlift in his ability to successfully execute the mission.

While it is premature to comment extensively about ongoing operations, the importance of the air bridge to Saudi Arabia and the Persian Gulf to protect vital U.S. interests in that region cannot be overstated. The deployment, known as Operation Desert Shield, represents the heaviest airlift tasking ever. As a result, for the first time ever, CINCMAC activated Stage I of the Civil Reserve Air Fleet to augment the capabilities of our dedicated airlift fleet.

The Iraqi forces that were poised on the Saudi border have, to date, been deterred by the immediate and forceful responses of the United States and the other nations participating in the deployment of forces to the Arabian Peninsula and Persian Gulf. This deterrence is not the result of any single Service or capability—deterrence has been established and sustained by the combined

[1] In the first two weeks of the Grenada operation, MAC flew 52 C-5 sorties, 653 C-141 sorties, and 286 C-130 sorties.

capabilities of all of the joint forces, and all of the elements of strategic mobility used to deploy them. But in viewing the first critical days of the deployment, airlift was (as would be expected) the only mobility tool able to bring forces to bear. A chronological review of the deployment is instructive. On August 7th, the United States, in consultation with Saudi Arabia and other allies, made the final decision to deploy forces. On August 21st, Secretary Cheney announced that there was a force in place capable of defending Saudi Arabia. In two weeks, airlift, along with prepositioning, enabled the United States to deploy a credible force half way around the world to lay the foundation for deterrence.

If combat is necessary, airlift will be even more vital—enabling the joint force commander to apply the right forces at the right place to produce success. And while the media was filled with headlines about the importance of airlift,[2] history indicates that sensitivity may dull with time. Eventually, some would-be budget cutters may attempt to draw the lesson that since today's airlift appears to have been sufficient to maintain deterrence, it is adequate for the future—forgetting how very heavily that airlift system was strained, or how potentially fragile was the period until sufficient forces were built up to slam shut what some have called Saddam Hussein's "window of opportunity."

Air Movements of National Influence

Direct combat operations form only one portion of airlift contributions to U.S. national security. Airlift forces provide our nation's leaders with the capability to enhance security conditions, strengthen security partners, and project U.S. influence—with limited or no use of lethal U.S. force. These air movements of national influence involve activities with relatively overt geopolitical overtones: the delivery of key materials, the movement of third country forces, the evacuation of American and foreign nationals, and other such actions. When such an operation needs to be carried out quickly—as they almost always do—airlift will be the key player. And the airlift fleet has been called upon many times in past decades to support allies and provide a means of achieving U.S. national security objectives.

This can be seen clearly in the Berlin Airlift of 1948, where the post-war fleet of U.S. transport aircraft achieved a remarkable victory—some have called it the most important of the Cold War. In the face of the Soviet blockade U.S. transports, with the aid of some allied transports, flew more than 277,000 sorties and delivered over 2.3 million tons of supplies to Berlin. At the peak of this resupply—the first time an entire city had been supplied solely by air—airlift delivered 13,000 tons a day. Code-named Operation Vittles, the airlift stopped the advance of communism in Europe while dramatically demonstrating airlift's potential. Berlin highlighted the fact that military airlift is an instrument for achieving foreign policy objectives not only in war, but in peacetime. In this particular case, airlift proved to be a more effective tool for underwriting national policy than bombers, warships, or tanks.

Few would question the significance of the Berlin airlift. Many are also familiar with the 1973 Israeli resupply effort. Days into the conflict, Israeli Prime Minister sent President Nixon an urgent personal message. Israeli supplies were running critically low—the fate of Israel itself was in serious doubt. Airlift responded. Over the next days, Air Force airlifters delivered more than 22,000

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[2] See, for example, UPI's "Airlift Taxing System," the *New York Times'* "Every 10 Minutes a Landing," or the *Washington Times'* "U.S. is Straining to Meet Schedule for Troops' Arrival."

tons of essential assets. But more than bulk, what distinguished the Israeli resupply was the fact that airlift delivered vitally needed equipment and supplies (things like TOW and Maverick anti-tank missiles, artillery ammunition, and aircraft spare parts) when they were critical to winning the fight. How important was the operation? Israeli Prime Minister Meir perhaps put it best when she stated airlift "...meant life to our people."

While the Berlin Airlift and the Israeli resupply are well known operations, few realize that Air Force airlifters have performed *well over 100* other such air movements of national influence in the post-World War II era—delivering material and personnel to allies when needed to support their security, defend mutual interests, and improve relations. What distinguishes these operations is that U.S. forces (except for airlifters) were not involved in direct combat operations. They range from the delivery of UN troops to Egypt to supervise the cease fire after the 1956 Suez crisis to the rushed shipment of weapons and ammunition to India when its borders were crossed in 1962; from the airdrop of Belgian paratroopers and delivery of additional forces to rescue 2,000 hostages held by Congolese rebels in 1964 to the delivery of Pan-African peacekeeping forces to Zaire in 1978; and from the delivery of a British peacekeeping force to Zimbabwe in 1980 to the airlift of a UN peacekeeping force to monitor the Iran-Iraq ceasefire in 1988. These operations have played an important role in supporting and achieving U.S. national security objectives.

Humanitarian Operations

Military airlifters have conducted humanitarian airlift operations for decades. Humanitarian airlift is typically conducted in response to disasters—hurricanes, floods, fires, plagues, and earthquakes—and draws upon essential characteristics of airpower: speed, range, and flexibility. When disaster strikes, speed of response is critical. Figure 1 illustrates the humanitarian airlift operations the Air Force has conducted in the 1980s alone—over 50 operations across the globe's surface that range from earthquake assistance in Mexico to flood relief in Bangladesh.

Humanitarian airlift also plays a role in supporting U.S. national security objectives by providing foreign populations with a favorable image of the United States. In indirect fashion, this can play an important role. For example, in October 1980, two major earthquakes struck Al Asnam, Algeria, killing thousands. Within hours, MAC airlifters began delivering hundreds of tons of disaster relief to the stricken nation. This action, carried out for humanitarian purposes, strengthened previously tenuous bonds between the two nations. A few months later, Algeria provided invaluable assistance to the United States, serving as the mediator in securing release of the American hostages from Iran. Was the Algerian initiative a result of the U.S. humanitarian assistance? Some Carter administration officials certainly thought so. Secretary of the Air Force, Dr. Hans Mark, wrote: "Our help to Algeria after the earthquake...led in turn to their help in persuading Iran to release the American prisoners....There is no doubt in my mind that our airlift forces are a major method that the United States has for exercising influence abroad."

How often has the Air Force been called on to perform humanitarian airlift operations? Again, the answer is more often than most would realize. Since World War II, airlifters have brought U.S. aid, concern, and assistance to dozens and dozens of countries in humanitarian response *to over 300 separate disasters*.

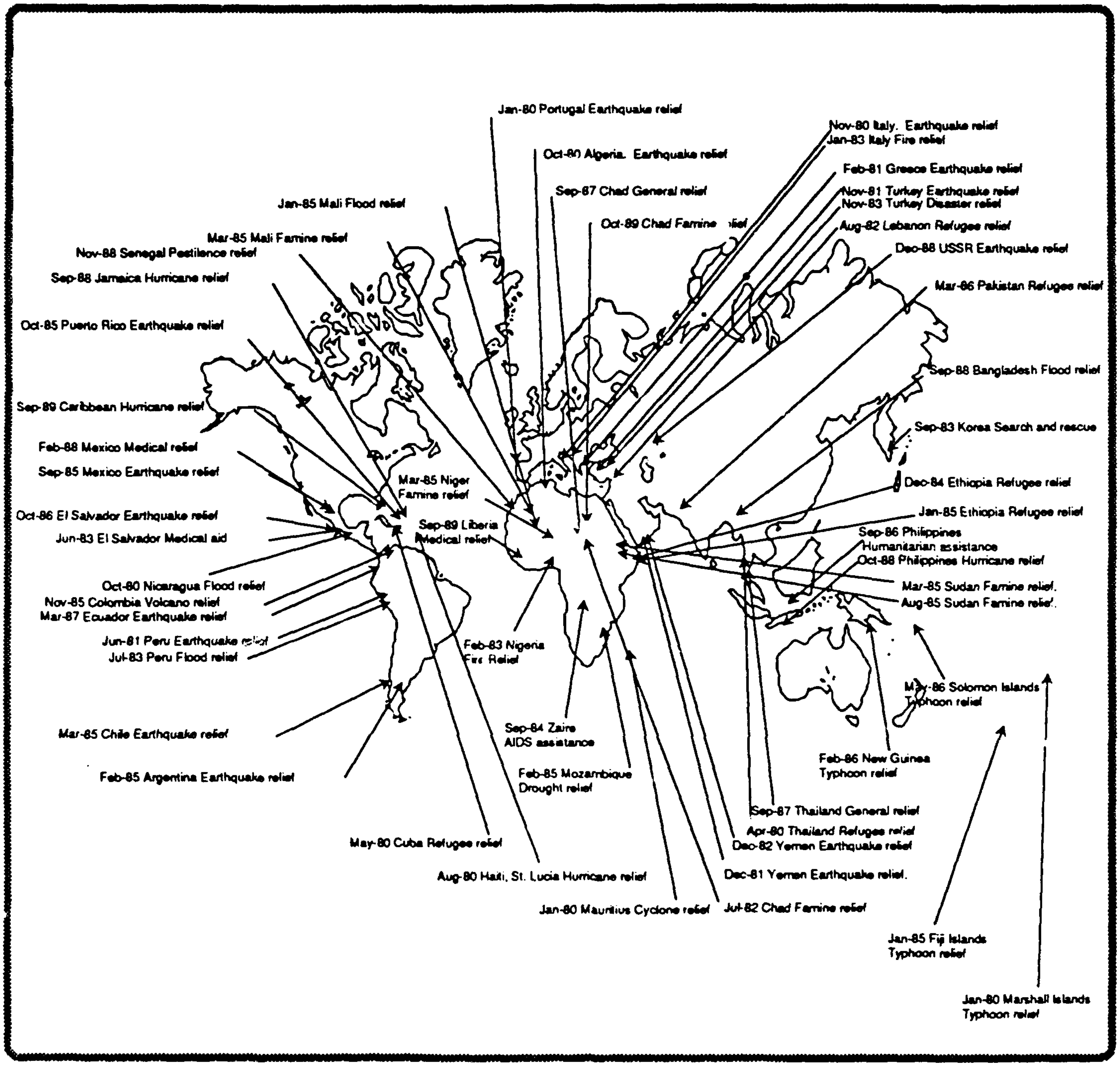

Figure 1—Humanitarian Airlift Operations in the 1980s

THE EMERGING STRATEGIC ENVIRONMENT

In the wake of recent dramatic developments in Europe, perhaps best symbolized by the fall of the Berlin Wall, some have leapt to the conclusion that airlift would be less essential in the future. Discussions in these circles quickly focused on how increased warning times for a European scenario would enable the United States to emphasize sealift and reduce our airlift capabilities. While Europe and warning times are a part of the equation, they are only that—a part of it. A comprehensive analysis of the emerging strategic environment clearly indicates that airlift will be *more*—not less—important to provide conventional deterrence and underwrite national security strategy in the future.

The overall Air Force assessment of the evolving security environment was laid out in a June 1990 White Paper entitled *Global Reach—Global Power*.[3] This document illustrated that a number of dynamic and rapidly changing factors—from the extraordinary developments in the Soviet Union and Eastern Europe to the spread of very sophisticated military capabilities around the world—are creating the potential for a significantly different environment as we approach the 21st century. While the probability of global war with the Soviet Union has diminished considerably, the easing of Cold War tensions does not, unfortunately, equate to the emergence of a tranquil world. As Saddam Hussein has so recently proven, the future world will likely witness crises brewing up quickly in unpredictable locations—crises caused by well-armed individual states working their own agendas. While not all such crises will threaten vital U.S. interests, some—like the Iraqi invasion of Kuwait—certainly will. U.S. forces must be able to provide a rapid, tailored response with a capability to intervene against a well-equipped foe, hit hard, and terminate quickly. The implication for U.S. forces is for fast, agile, modernized conventional capabilities.

Global Reach—Global Power highlighted the fact that strategic mobility lies at the heart of a credible deterrent posture in such an environment—without the capability to project forces there is no conventional deterrent. To provide mobility for U.S. forces, the nation has historically relied on a balance of the complementary capabilities of what has been called the mobility triad: airlift, sealift, and prepositioning. Each has advantages and disadvantages—we capitalize on each method's virtues to compensate for the others' limitations.

Prepositioning involves placing war material ahead of time in potential conflict locations—a more difficult task today given the unpredictability and instability in the environment and the accelerating pace of global change. Although war reserve stocks often can be used to fill prepositioning sets, sometimes the nation must purchase duplicate sets of equipment (one for prepositioning, the other for training), which increases costs. Prepositioning—particularly as we look for ways to reduce presence in Europe—can be valuable, but remains the most inflexible of mobility tools.

As Desert Shield has shown, sealift is vital to deploy heavy armored forces and the bulk of sustaining supplies. Sealift will tinue to be an important mobility tool as forward presence declines. But against sealift's muscular capacity must be weighed its lack of responsiveness. For example, as indicated earlier, in the 1973 October War, Israel's situation had become desperate. In responding to this crisis, sealift delivered 74% of the total resupply tonnage—and that bulk was important to re-building Israeli capability. But the first ship arrived

3 See *The Air Force and U.S. National Security: Global Reach—Global Power* (Headquarters, United States Air Force, June 1990).

several days *after* the war had ended.[4] In terms of impact on that conflict, sealift had little or none.

The mobility tool uniquely suited for an environment of uncertainty with widely dispersed potential flashpoints is, by definition, the most flexible and responsive one—and that clearly is airlift. When an operation needs to be carried out quickly, airlift will be the key player. And while one must always be cautious of defining any single example as "the way of the future," the sudden Iraqi invasion of Kuwait was exactly the kind of security threat forecast by *Global Reach—Global Power*: a sudden, unpredictable action by a well-armed rogue state that directly threatened U.S. interests. It will not be the last. In response, as outlined in *Global Reach—Global Power*, "...our force planning calls for an increased emphasis on force projection capabilities—even more flexible, rapidly responding forces with global reach."

The challenge that we face as a nation in meeting our global mobility needs is to take advantage of the attributes of each leg of the mobility triad in the most cost-effective manner possible. To say that airlift will become more important is not to deny the value of either pre-positioning or sealift. Given the magnitude of overseas force withdrawals under consideration (in several areas, not just Europe) the legs of the mobility triad each have importance and cannot be simplistically viewed as competitive—they are complementary and synergistic. We must capitalize on the unique attributes of each as appropriate to meet the realities of the future security environment.

THE C-17—THE RIGHT AIRLIFTER FOR THE FUTURE

Exhaustive studies over a number of years have produced a single, consistent answer—the C-17 is the right airlift aircraft for the future.[5] There is considerable logic to support those conclusions—logic, again, that is enhanced by developments in the emerging security environment.

The Evolution of the C-17 Program

The concept of a flexible, deployable, largely CONUS-based force—a concept today supported by many strategic analysts—is not actually new. Studies in the early 1960s strongly advocated such a force posture to reduce the costs associated with overseas forces and increase U.S. flexibility. The result was the development of a true strategic airlifter—the jet-powered C-141A Starlifter. This workhorse entered service in 1965. It could carry double the cargo of a C-130, over much greater distances, at almost twice the speed. The C-141, in conjunction with the C-130, promised a dramatic increase in the responsiveness of U.S. airlift capabilities. C-141s could deliver cargo to rear area bases—C-130s could then transport the material to forward areas closer to employment locations.

The C-130 and C-141 shared a fuselage width and height of common size—these aircraft could carry bulk cargo, such as palletized loads, and many smaller vehicles. But increasing amounts of equipment essential to the fighting power of ground forces (tanks, larger trucks, other armored vehicles, helicopters, etc) could not fit within the confines of these two airlifters. Analysis in the 1960s concluded

[4] Sealift supplies might have taken even longer to arrive had not that first ship been diverted from its original destination to sail instead for Israel.

[5] Some of the key studies which supported the need for the C-17's capabilities include: C-X Task Force Requirements Analysis (1980: USAF/Army); The Congressionally Mandated Mobility Study (1981: OSD); Airlift Master Plan (1983: USAF); The World-Wide Intra-Theater Mobility Study (1988: OSD); The Revised Inter-Theater Mobility Study (1989: OSD) and The Major Aircraft Review (1990: OSD).

that C-141s and C-130s could not transport one-third of the equipment of an infantry division—and even less of an armored division's equipment.[6]

The conclusion of the Department of the Defense, committed to enhancing the flexibility of an increasing CONUS-based reserve, was to draw upon advances in aerospace technology to create an even larger strategic transport. This aircraft would be capable of carrying these large pieces of equipment—what the Air Force refers to as "outsize." Even as the C-141 was in the midst of full-scale development, a contract was awarded for the advanced C-5A Galaxy transport, which first flew in 1968. The world's first "jumbo jet," the C-5 was at the time the world's largest aircraft—and the first "outsize" jet airlifter. It was capable of carrying not only three times the load of the C-141, but outsize equipment such as tanks and helicopters.

As the last of the C-5A production run was ending in the early 1970s, research had begun on developing a successor to the C-130, a program known as the Advanced Medium Short Takeoff/Landing Transport (AMST) aircraft. Two prototypes were constructed—the Boeing YC-14 and the McDonnell Douglas YC-15—which engaged in a flyoff in 1976 and 1977. Both of these aircraft, which provided a wide body cargo box that would accommodate the outsize nature of Army firepower, employed jet engines and a variety of "powered lift" concepts aimed at significantly reducing both takeoff and landing distances. These performance improvements offered significant potential to increase the number of airfields available for forward delivery of outsize cargo—and thus increase flexibility and effectiveness.

Original plans had been to decide on an AMST winner and launch full scale engineering and development work in 1978. But world events soon focused attention on increasing U.S. long-range airlift capabilities. The Iranian revolution shattered the United States' "Two Pillar" strategy for the Persian Gulf, whereby Iran and Saudi Arabia would act to encourage regional stability and deter Soviet aggression. In October 1979, President Carter announced the formation of a Rapid Deployment Force (later to become CENTCOM). Over the next two months, events in this "arc of instability" combined to make the establishment of a credible expeditionary force even more vital. In November 1979, Iranian radicals seized the American embassy in Teheran; almost concurrently, Islamic fundamentalists attacked the Grand Mosque in Mecca; and only one month later, the Soviets invaded Afghanistan.

The vast distances involved in getting combat forces to the Persian Gulf—distances on the order of 7,500 nautical miles—led to renewed focus on long-range or strategic airlift capabilities. The AMST program was terminated. The Department of Defense initiated studies aimed at creating a long-range aircraft that capitalized on the technologies demonstrated in the two AMST aircraft designs. In December 1979, the DoD launched the groundwork for the C-X (cargo experimental) program, believing that fundamental changes in the world environment required a re-emphasis on strategic airlift needs, particularly for meeting contingencies in Southwest Asia. The worldwide requirements analyses showed that the new airlifter would have to fly long ranges and carry outsize cargo. It would also have to provide solid tactical performance and agility to open up more airfields for global operations. In the spring of 1980, the Air Force requested proposals from American industry.

The request for proposal was unique in that it defined the movement tasks and the operational environment, not detailed aircraft specifics. Contractors were

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[6] The percentages of ground force equipment that will fit into C-141s and C-130s has decreased *considerably in* recent decades.

given the problem—four scenarios, the units to be deployed, and the required closure times—and asked to develop an efficient design to meet mission requirements at the lowest life cycle cost.

In January 1981 Boeing, Douglas, and Lockheed submitted their C-X proposals and the process of evaluation began. A Congressionally mandated study on mobility requirements proved a critical tool for determining the size of the program. The study also illustrated the utility of tactical capability in strategic lift, which would permit "direct delivery" and operations into small austere airfields. In August 1981, the Secretary of Defense announced McDonnell Douglas as the winner of the C-X competition—and the winning design was designated as the C-17.

The development of the C-17 would take several years, but changes in the international environment led to a decision that an interim augmentation of airlift capabilities was needed. The Secretary of Defense certified the need for the C-17, but directed that the DoD should pursue nearer term airlift augmentation. In January 1982, the Deputy Secretary of Defense and the Secretary of the Air Force, after examining several options, recommended the procurement of 50 C-5Bs and 44 KC-10s (a converted civil aircraft capable of use as both a tanker and a transport) and, for budgetary reasons, delayed development of the C-17.

With the conclusion of the KC-10 and C-5B procurement, development of the C-17 once again became the focus of U.S. airlift enhancement plans, particularly as retirements in the C-141 fleet loomed on the horizon. As the 1980s drew to a close, a series of dramatic developments in the Soviet Union and Eastern Europe led the Secretary of Defense to initiate a further review of the C-17 program (along with several others) to reassess the need for its capabilities in light of the changing international scene. The review had two objectives: 1) Did the United States still require modernized inter-continental airlift capabilities; and 2) if so, was the C-17 still the most cost-effective means of supplying that capability?

The DoD review examined U.S. national military strategy and reaffirmed that conventional deterrence of aggression against U.S. interests and allies required forward presence, power projection, early responses to crises, and the capability to effectively support regional allies and friends. The rapid changes in the world combined with a decreasing U.S. forward presence underscored the need for flexible, ready, and mobile forces, capable of attaining decisive superiority where and when required. The review concluded that a strong strategic airlift fleet remained vital.

The Secretary's review explored several methods of providing the required airlift capability in exhaustive detail. These included:

- Service life extension of the C-141 force
- Procurement of something else (such as C-5s or modified civil airframes)
- Procurement of the C-17

A service life extension program (known as SLEP) for the C-141 was evaluated carefully. The C-141 airframe life originally stood at 30,000 hours. To improve its capabilities, the USAF had carried out a modification program in the late 1970s and early 1980s which stretched the airframe (thus increasing the cargo that could be carried) and added aerial refueling capability. The stretch of the aircraft increased the normal weights carried, which placed additional strains on the airframe. In addition, low level flying and aerial refueling—both of which became increasingly important as new employment concepts of operations were developed—added more stresses on the airframe and caused additional fatigue. For example, strains on the aircraft at low level are much higher than at normal cruise; heavyweight aerial refueling can increase strains by up to 20 times. These factors, along with the decades of flying, had consumed a good deal of service life—the fleet in mid-1990 stands at an equivalent average of about 32,000 hours. The Air Force had initiated a relatively affordable repair and replace program to extend the service life to 45,000 hours. But even under this plan, the first C-141s would be forced to retire in the mid-1990s. To extend the service life further would require a major rework of the airframe—a new wing at a minimum—and possibly new engines. This would be expensive—initial cost estimates for airframe rework and new engines ran in the neighborhood of 13.5 billion dollars—and extensive additional engineering would be required to assess the problems involved. Such a program would not improve capabilities in any case. The C-141 cannot carry outsize cargo and requires relatively long runways for operations. And C-141 SLEP would only "kick the can down the road," forcing the nation to readdress the requirement to procure a new airlifter in a relatively few years.

In addition to the high cost compared to the return, another factor mitigating against the C-141 SLEP was risk. Even with a SLEP, significant technical uncertainties were involved in creating a service life of 60,000 hours. The Air Force has no experience trying to make an aircraft last that long. And while some commercial operators have experience in that edge of the envelope, civil aircraft fly benign flight profiles and do not have to suffer the rigors of military flight regimes. What could very well happen with a C-141 SLEP would be the discovery, sometime in the future, of a significant problem with the aging airframe—a problem which could ground a major element of our airlift capabilities. For example, the Royal Air Force in the 1960s depended heavily upon the Valiant heavy bomber/tanker to meet its nuclear deterrent commitments. Discovery of fatigue-induced wing cracks forced the immediate (and permanent) grounding of the entire force in 1965. The Department of Defense prudently judged that we simply could not afford to take that kind of risk with our critical airlift force. Indeed, in early 1990, C-141 wing cracks developed that required reductions in combat airlift training.

The civil aircraft option was quickly dismissed for a number of reasons. First of all, despite what some might think, commercial aircraft are *not* a bargain compared to dedicated airlifters. Recent sale prices indicate a Boeing 747, for example, costs between 150 and 200 million dollars, and that's an aircraft produced at very efficient production rates. At the production rates recommended by the Secretary of Defense's review, the C-17 would be less expensive.[7] The B-747 would still require additional expensive modifications—strengthened floors, aerial refueling capabilities, installation of larger doors, etc. And at the end of all that, the result would be an airlifter that could only operate into major airfields with expansive ramps and extensive support equipment; an airlifter without enhanced survivability measures that was not designed for the rugged military flight environment; an airlifter without airdrop capabilities—in sum, an airlifter that would be considerably less useful than a C-17.

[7] The number of aircraft produced each year has an important impact on the cost of the airframe. To produce aircraft requires maintaining large facilities and trained cohorts of skilled workers, which must be maintained regardless of production rates. Obviously, if production rates are reduced, the cost per airframe tends to increase.

The Air Force has decades of experience with trying to convert civil aircraft to military purposes. The results have usually been less than satisfactory.[8] The high cargo deck of commercial aircraft (typically about 16 feet off the ground) limits their capability to carry military rolling stock, firepower, or outsize equipment, requires expensive special loading and unloading equipment which they cannot carry themselves, and causes significantly longer loading and unloading times. As a result, civil aircraft provide less throughput (the amount of cargo that can be put through a given airfield in a given time) than purpose-built airlifters. Large commercial aircraft require acres in which to maneuver—they can only operate in large, well-equipped airfields and their lack of ground maneuverability limits the number that could be parked on ramps at objective airfields, again reducing throughput. The typical commercial airliner or freighter flies a benign profile—takeoff, cruise at high altitude, and land—these aircraft are not designed nor built to fly in rigorous military flight regimes and profiles. And procurement of large airlifters adapted from civil aircraft would still require the procurement of additional C-130 aircraft to deliver cargo from rear area airfields to forward sites.

Procurement of C-5s was also examined (as it had been in the past) and—again—it was shown not to be the answer. First of all, C-5s did not compare well with the C-17 operationally. The sheer physical size of the C-5 limits its flexibility and the number of airfields in which it can operate. And because it is so large, the C-5 literally shuts down some fields after it lands. More comparisons on the performance of the two aircraft follow in a later section, but both performance and cost considerations played key roles in the decision to reject the C-5 option. To meet required capabilities, procurement of C-5s would also require procurement of a significant number of C-130s to deliver cargo deposited by C-5s at major aerial ports forward—and since outsize cargo can't fit in C-130s, it would have to travel forward by road or rail. The procurement cost alone of a C-5/C-130 option was much greater than the planned C-17 program and, given the relatively high operations and supportability costs of the C-5, the life cycle costs of the C-5 option were dramatically higher.

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8 Historically the United States has both adapted existing military and civil airframes and developed dedicated aircraft. Experience derived from combat operations demonstrated the problems of adapting commercial airframes and led to the design of purpose-built, more capable airlifters. In Korea, for example, the purpose-built C-119 "Flying Boxcar" entered service. The C-119 featured the true hallmark of a purpose-built airlifter—a cargo floor low to the ground to speed onload and offload operations. The requirement for a low cargo deck has perennially posed aircraft designers with a number of issues. To keep the floor low to the ground, engineers must typically place wings on the top of the fuselage, which typically means that the landing gear must be placed on the bottom of the fuselage. To withstand the heavy stresses inherent in combat airlift operations, a separate strong structure to attach the landing gear must be housed in the lower fuselage. This adds additional weight while the landing gear sponsons increases aerodynamic drag. But these penalties are worth incurring for the increased efficiencies offered by the low-deck airlifter, particularly in combat conditions.

Most commercial airliners draw the basics of their design from the famous B-707 series. In this classic design, the wings joined the fuselage underneath—and this wing-fuselage box formed a naturally strong point for the attachment of the landing gear. Jet engines were hung in pods hanging from below the wing. The landing gear was designed to place the engines at a high enough level to prevent the engines from sucking in runway debris. One key advantage of this classic design—emulated in just about every commercial jetliner since—was tremendous weight and aerodynamic drag reductions through the natural join of the wing and fuselage. A separate structure did not need to be created for attaching the landing gear, which saved weight; the landing gear could be carried inside the wing/fuselage box, thus reducing drag. In combination, the reduction of weight and drag created a very fuel efficient airframe—a critical issue to airlines. Civil airlifters have proven not totally satisfactory as airlifters. The cargo floor of such aircraft are typically 16-17 feet off the ground. To unload heavy bulk cargo from these heights requires large specialized materials handling equipment and unloading operations are less efficient when compared to low deck aircraft. Delivering vehicles is also rendered problematic because of the height of the floor—with a low deck aircraft, vehicles can simply be driven off.

The conclusion of the detailed analysis was that the C-17 was not only the most cost-effective choice, but that it was the only logical choice. As Secretary of Defense Cheney testified to Congress, the study showed: "The C-17 offered the most capability at least cost in every case." Affordability concerns led to a reduction in the planned buy—from 210 aircraft to 120—but strong support continued for the C-17's unique capabilities.

C-17 Capabilities

The C-17 combines current technologies to create what is in many respects a revolutionary capability—a capability the Air Force calls "direct delivery." Cargo and personnel can be flown from the United States or elsewhere *directly* to where they are needed. The need for this capability was developed on the basis of decades of extensive experience with (and lessons learned from) airlift operations in combat, crisis, and peacetime. In short, the C-17 combines the advantages of a strategic airlifter like the C-5—range, speed, aerial refueling, and payload (including outsize cargo)—with those of a tactical airlifter like the C-130—survivability, ability to operate on short, unimproved airfields, agility and maneuverability in the air and on the ground, and the ability to employ different methods of airdrop. The aircraft is highly flexible, designed to very efficiently meet the nation's airlift needs across the entire range of potential scenarios. This is particularly valuable in light of the increasingly uncertain future security environment.

The evolution of aviation technology has led to the current practice of "sequential" airlift. Long-range airlifters, such as the C-141 and C-5, transport cargo to major airfields; the cargo is then offloaded from the strategic airlifters, stored as necessary, and transferred to C-130s. The latter then deliver the cargo to smaller forward airfields closer to the point of need. C-130s, however, cannot handle outsize equipment. This equipment must be carried by road transport or rail—it obviously cannot arrive in as timely a fashion as airlifted material and in some potential Third World scenarios, the location where the equipment is needed may be hundreds, even thousands, of miles from the major aerial port.

A primary objective in the design of the C-17 was to increase the number of potential airfields available to this "strategic" airlifter so that the aircraft could deliver directly to the forward area. This capability increases the speed at which U.S. forces can be built up (by eliminating the transfer of cargo to C-130s or rail/road movement) and decreases the resources required to move them. For each C-17 that could "directly deliver" cargo where it was needed, up to four C-130 sorties would be freed for the movement of tactical cargo. This same capability, funded for military reasons, would also pay important benefits for humanitarian airlift operations into devastated areas.

During the development of the C-17, some questioned whether the aircraft's direct delivery capability would actually be used in combat operations, noting that it is one thing to risk a C-130 in forward areas, but quite another to risk a C-17. The actual employment decision is one that will have to be made by the CINC at the time, perhaps based on the importance of the objective, but such questioning ignores the basic strategy of the United States—deterrence. Our objective is to deter conflict—and deter it by rapidly building up forces wherever they are most critically needed. The C-17 will allow us to do that and in addition, it will allow us to leap over congested airfields and deliver integral combat units ready to deter or to fight and win. And with the introduction of the C-17 comes new lateral mobility to rapidly reposition combat units and firepower within a theater to cope with fluid situations. And should the C-17 be placed in harm's way, the extensive design attention given to survivability will pay large dividends.

Some of the advantages the C-17 would provide can be seen in several recent airlift operations. Take, for example, the 1976 humanitarian airlift operation to eastern Turkey, which was devastated by earthquakes in that year. MAC airlifters delivered more than 1,000,000 pounds of relief supplies. To conduct the operation over a three day period, 30 C-5/C-141 airlift sorties flew into a main airfield, after which 40 C-130 sorties were required to deliver the material where it was needed. If the C-17 had been available, only 14 C-17 sorties would have been required—total—and the operation could have been conducted in just over a day.

1983's Operation AHUAS TARA, where material and personnel were airlifted to the small airfield of Puerto Lempira in Honduras, offers another useful example. Because Puerto Lempira could not accomodate strategic airlifters, two C-5s and 32 C-141s flew material and personnel to Honduras' large airfield at La Mesa. C-130s, tasked with moving the cargo and people from La Mesa and Tegucigalpa, flew 232 sorties in the course of the operation. To move the same material in less time with the C-17 would only have required 19 aircraft (each C-17 would have to fly one direct delivery sortie from the CONUS to Puerto Lempira and a shuttle sortie between required bases). The C-17's flexibility would provide a dramatic savings of both time and resources.

The same versatility that allows direct delivery enables the C-17 to swing from the strategic airlift role to the theater airlift role. It allows the joint force commander to apply the C-17 where ever it is needed to solve his most critical mobility problems.

Why such a major increase in capabilities? The answer lies in the set of inter-related technologies and design criteria that have been incorporated into the C-17. These include: aircraft size; propulsive lift technology; and ground maneuverability.

When looking at the first C-17 airframe as it moves down the production line in Long Beach (it is scheduled to conduct its first flight in mid-1991), most observers are struck at how closely the aircraft resembles the C-141 in external dimensions. The chief difference, at least externally, is the C-17's fuselage, which is nearly as wide and high as a C-5 and thus provides the aircraft with the capability to carry outsize cargo. But the C-17's wingspan is just 11 feet greater than a C-141.[9]

The reason for the C-17's dimensions relate to years of experience in operating the C-141 and C-5. The C-141, derived from late 1950s technology, was designed primarily to fly from the United States to major airfields overseas—it required a relatively lengthy runway. The C-5, on the other hand, was designed with a high lift wing to land on shorter runways and high flotation landing gear to operate on runways with lower strengths.[10] But years of operational experience with the C-5 demonstrated that just takeoff/landing performance and high flotation landing gear—the major specifications that C-5 designers worked under in developing the system—did not permit the Military Airlift Command to employ smaller, more austere airfields *on a routine basis*.

With reduced payloads, the C-5 has the capability to land within the length of some of these strips, but many of these runways are too narrow for the C-5 to land on, and others are too narrow for it to turn around. And its sheer physical

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9 The wingspan itself is only five feet greater than that of a C-141, but the winglets (which reduce drag for greater efficiency) slant slightly out, adding approximately six more feet.

10 For example, B-747s require runways with a Load Classification Number of almost 100; a C-5 can land on runways with a LCN rating of only 37.

size generates a host of problems. The width of its wingspan often creates a situation where a C-5's engines overhang the edges of the runway. This raises the potential that the engines could ingest foreign objects (potentially destroying the engines) while the blast from the engines could damage runway facilities and litter the airfield with rocks and other debris (thus increasing the risk of foreign object damage for subsequent aircraft). The aircraft is so large that crews encounter difficulties in maneuvering on small airfields which require using narrow taxiways to reach parking ramps—in some cases they cannot. Limited ground maneuverability constrains the number of C-5s that can be placed on a single airfield ramp for loading and unloading. And when maneuvering on the ground the jet blast from its four massive engines can cause damage to structures, equipment, other aircraft, and personnel. In short, the C-5 can, if required, sometimes employ smaller airfields, but the problems raised by the aircraft's unprecedented size make such operations impractical for routine operations and impossible for major airlift requirements.

The C-17 provides the nation with an airframe that can carry the same types of cargo as a C-5 (although not quite as much in terms of tonnage), but in a more compact vehicle. This compactness in turn greatly eases the problems of operating a long-range airlifter into small airfields. The C-17's ability to operate into small austere airfields on a routine basis is not just a result of physical size—it is created by the merging of several other proven technologies: the use of the powered lift based on an externally blown flap principle, related directed flow thrust reversers, and avionics aids for aircrew that permit precise landings.

Externally blown flaps were first employed on the YC-15—the prototype AMST airlifter developed and extensively tested by McDonnell Douglas in the early 1970s. With this system, flaps are lowered and placed directly in the jet engine's exhaust stream (see the diagram of a C-17 engine and exhaust stream at figure 2). Air deflected by the under side of the flaps adds a near vertical lift component, while, because of the Coanda Effect, air blowing over the top of the flaps also increases lift. The use of these flaps enables the C-17 to take-off in very short distances indeed compared to conventional aircraft. Perhaps more importantly, the powered high-lift system gives the C-17 exceptional landing performance. The C-17 can approach runways at much lower speeds and steeper glide paths than conventional aircraft; it can thus land within very short distances with very heavy cargo loads—less than 3,000 feet with over 167,000 pounds of cargo.

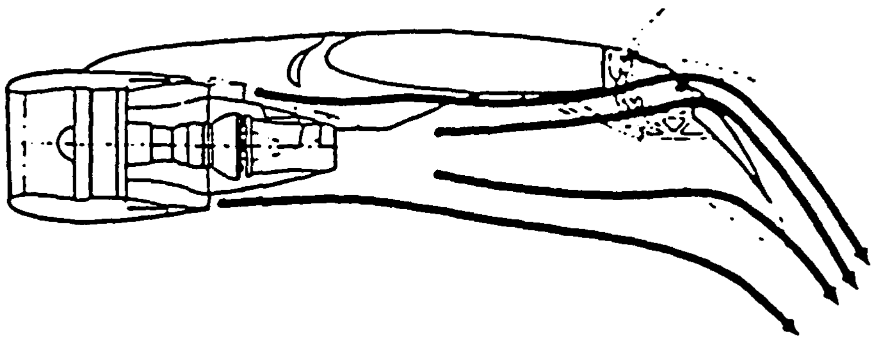

Figure 2—Powered lift based on externally blown flaps

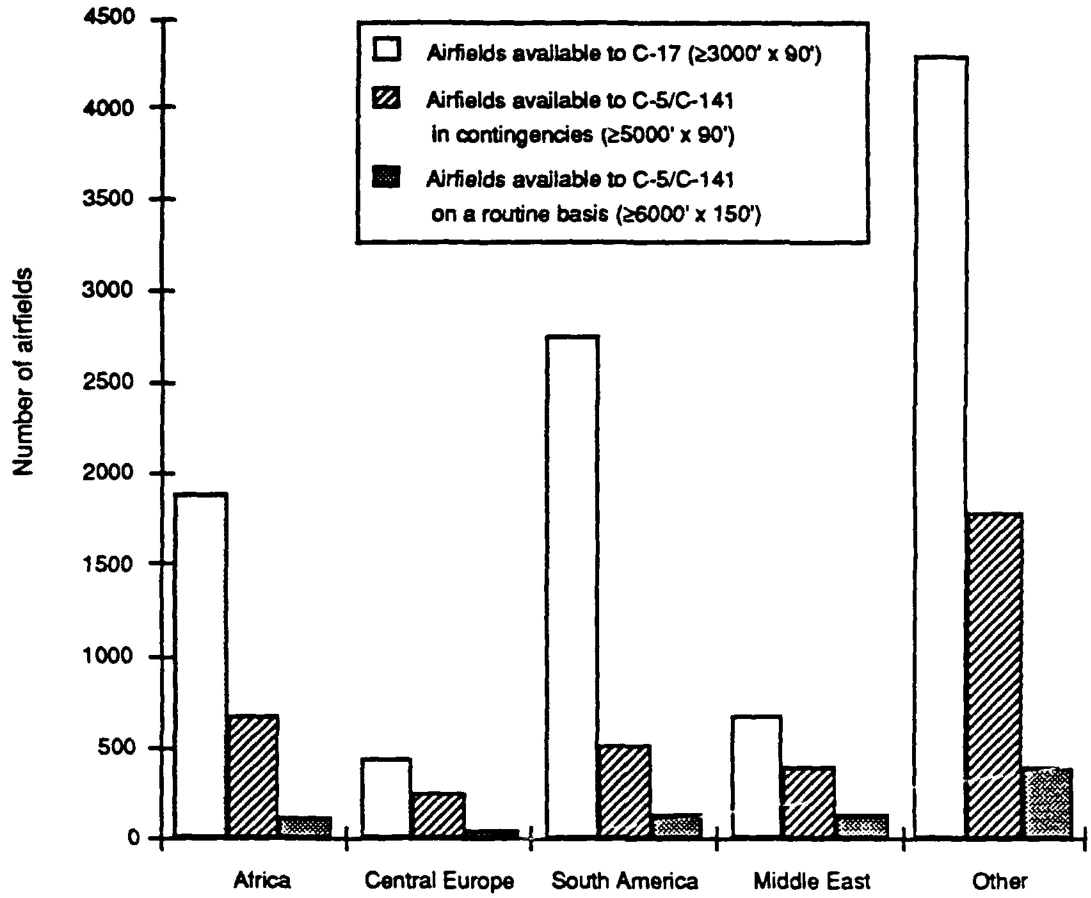

Figure 3—Airfields available to airlifters in the Free World
(less United States)

The C-17's short field capabilities are further enhanced by the landing gear and avionics. Landing gear design allows landing sink rates of up to 15 feet per second while the crew employs head-up displays (HUDs), much like those used on modern fighters, to provide precise aimpoint control—something of critical importance when dealing with small airfields. The HUDs, in conjunction with the aircraft's avionics suite and flight control systems, enable the crew to select the precise point on the ground where they want the aircraft to touch down. Consequently, the pilot's aim point can be moved close to the leading edge of the runway, reducing the safety margin required for less precise aircraft, and thus the length of runway required.

Figure 3 illustrates how the C-17's impressive small austere airfield capabilities expand the options available to planners and operators conducting airlift operations. In essence, three times as many airfields are open to the C-17 on a *routine* basis as are available to the C-5 and C-141, even on a contingency basis. In the recent operation in Panama, for example, only two airfields could accommodate C-141s and C-5s. If the C-17 had been available, five airfields could have been employed. It says something about the pace of technological advance that the C-17 can carry 18 times the payload of a DC-3—and yet land on shorter runways than that famous aircraft.

The capability to land at a short strip, however, does not automatically translate into the capability to employ that strip on an operational basis. One of the critical features of the C-17 is that it will be the first operational jet airlifter capable of backing up on a routine basis without the aid of ground tugs. It also utilizes narrow track landing gear for agility on constricted taxiways. The C-17's compact size and exceptional ground maneuverability provide the capability to efficiently use limited ramp space. This capability is critical in theaters that contain numerous small airfields with narrow taxiways and confined parking ramps.

The C-17's reversing capabilities stem from its directed-flow thrust reversers (see figure 4). Most jet transports employ thrust reversers when landing—deflectors that redirect engine thrust from propelling the aircraft to braking the aircraft. But employing conventionally-designed thrust reversers for ground maneuvering typically creates two major problems that prevent their use except in extreme emergencies. First, engines often overheat as they ingest hot gases thrust past their intakes by thrust reversers. Second, the blast from jet engines can damage airfield structures, equipment, and personnel. The end result is that C-141s, C-5s, and commercial aircraft must be given large amounts of ramp space when offloading (thus permitting them to use engines on forward thrust) or provided with ground tugs. In most of the smaller airfields of interest to many airlift operations, ground tugs are not available—and even if available, are simply not efficient when compared to a highly maneuverable aircraft. The C-17's thrust reversers direct engine thrust forward and up, so that the aircraft can back (even up sloping ramps) without overheating its engines or disrupting airfield operations.

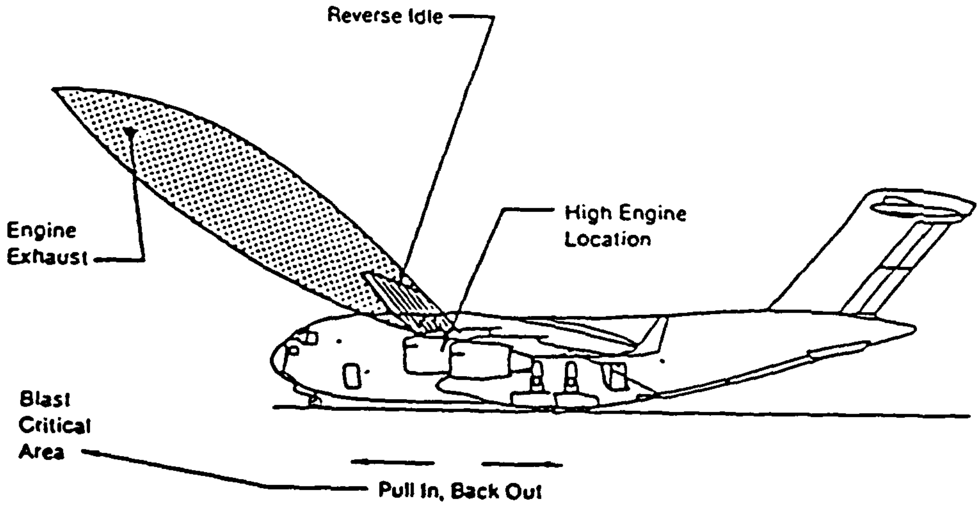

Fig. 4—Advanced thrust reverser allows agile ground operations

The capability to back up under its own power adds a number of critical advantages. When maneuvering on the ground, the C-17 can conduct three point turns to reduce its turning radius to only 80 feet—compared to 137 feet for the C-141B and 148 feet for the C-5B. This permits the aircraft to turn around within the width of most smaller runways—and utilize the narrow taxiways and small ramps associated with smaller airfields. The smaller physical dimensions of the aircraft and narrow track of its landing gear compared to a C-5 also allow it to avoid the numerous obstructions that are often found at such airfields. Decades of operational and combat experience with the C-130 (the only U.S. airlifter currently in the inventory that backs up in routine operations) have proven the value of the ability to back up to get maximum utilization out of crowded ramps.

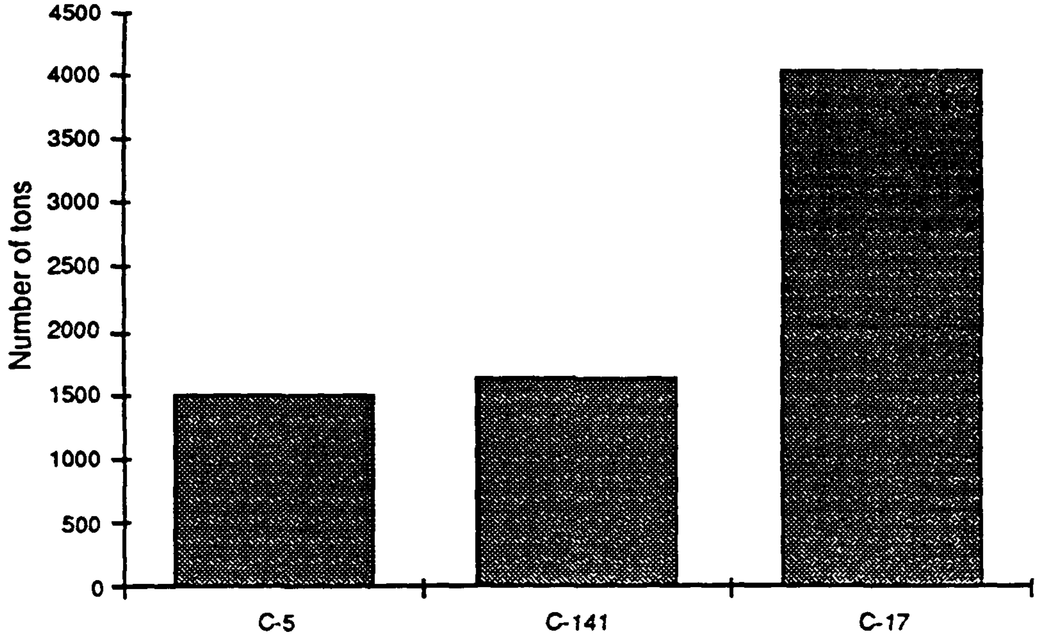

Fig. 5—Airlift throughput capabilities for a 500,000 square foot ramp

Notes: Calculated using the following factors.

Aircraft	Payload (tons)	Maximum Number of Aircraft on Ground	Cycles Per Day	Throughput (tons)
C-5	68.9	3	7.4	1529
C-141	27.5	6	10.7	1765
C-17	48.3	8	10.7	4134

The C-17's capability to maneuver on the ground like a tactical airlifter means that more C-17s can park and offload on a ramp than either C-5s or C-141s. For example, on a 500,000 square foot parking ramp, eight C-17s can be parked and offloaded, compared to only six C-141s or three C-5s. As illustrated by Figures 5 and 6, these capabilities allow the C-17 to deliver more cargo than our other long-range airlifters—to increase throughput capability—within the limits of a given ramp space.

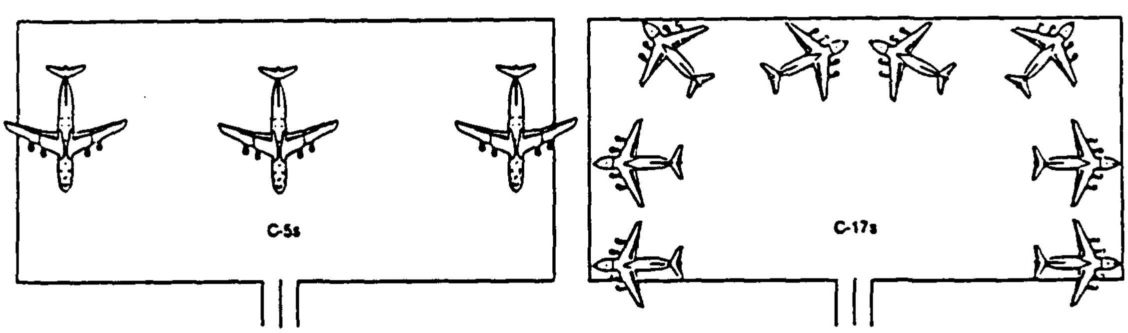

Figure 6—Diagram of a 500,000 square foot ramp used for data in chart above

While there are many other performance advantages provided by the C-17, enhanced survivability is among the most important. The C-17's beefed up airframe has been designed to easily withstand the rugged military flight environment. It can fly to objective airfields at high altitudes—above the range of anti-aircraft artillery and hand-held surface-to-air missiles—and then spiral down at extraordinarily high descent rates (up to 20,000 feet per minute). Or it can penetrate at high-speeds and low-altitudes to take advantage of terrain masking. It can slow from enroute speed of 350 knots to airdrop speed of 130 knots (where an airlifter is most vulnerable) very rapidly, and then accelerate quickly back to enroute speed. These are major improvements over the C-141 and C-5.

To reduce the effects of combat damage, the C-17 will feature separated and redundant systems and fuel tank inerting to prevent fire or explosion within the tanks. Inerting is provided by the on-board inert gas generating system (OBIGGS). OBIGGS uses nitrogen-enriched air to reduce oxygen concentration levels in the tanks well below that necessary for combustion. How important are self-inerting fuel tanks? Consider Operation Just Cause. MAC lost no aircraft in that operation, but 11 C-130s *did* take hits, eight of them in the fuel system. The C-130, like the C-17, is designed for survivability. The protection in their fuel tanks worked. The outcome might have been less favorable had C-141s, which have no such protection, taken hits in their fuel systems.

The ability of the C-17 to employ a full range of aerial delivery techniques will add to its value. It will be able to airdrop paratroopers, equipment, and supplies as C-130s and C-141s do today. It will be able to employ the Low Altitude Parachute Extraction System, which only the C-130 can currently do. And, it will be able to airdrop and extract outsize equipment which no aircraft does today. It will be able to perform airdrops precisely at night or in the weather, again increasing survivability. Combined with the speed, air maneuverability, and load carrying ability of the C-17, these capabilities will open up new tactics to increase airlift's effectiveness in the combat environment.

Life Cycle Cost

A critical aspect of the C-17's design was life cycle cost—the expenses involved in acquiring, operating, and supporting the fleet over the service life of the aircraft. With aircraft service lives now projected to be many decades, life cycle cost becomes a critical issue in maintaining force structure. The C-17 was designed from the outset to operate more efficiently and cost-effectively than any airlifter in the force. For example, the C-17 will be able to deliver approximately double the cargo of a C-141B for approximately the same operating cost. This cost effectiveness is the product of several interrelated aspects: fuel efficiency, crew size, and reliability and maintainability.

The C-17 features the Free World's largest supercritical wing and winglets. The wing's design reduces drag and weight, as do the fuselage afterbody strakes. The use of advanced composite materials in the C-17 permitted weight savings of more than 4,000 pounds than if standard materials had been employed. Together, reductions in drag and weight reduce fuel consumption, which in turn reduces day-to-day operating costs.

The C-17 uses the F117-PW-100 engine, an off-the-shelf commercial engine which currently enjoys over 2 million hours of flight time on the Boeing 757 airliner. Thus the Air Force is able to capitalize on years of extensive testing and experience with the powerplant and to integrate the engine into the C-17 at minimal developmental cost. In commercial service for six years, the engine is demonstrating exceptional reliability. An advanced turbofan with a thoroughly tested full-authority digital electronic fuel control, the F117-PW-100 offers the lowest fuel consumption per unit of thrust of any engine in its thrust class to help make the C-17 a highly fuel efficient aircraft—in a world in which fuel costs are playing an increasingly powerful role in determining operating costs. The outstanding performance, fuel efficiency, and reliability of the engine are—like many other aspects of the C-17—guaranteed by the warranty that will be discussed in more detail later. The warranted engine inflight shutdown rate of not more than one every 20,000 hours means that C-17 pilots may fly their whole careers without having to shut an engine down due to an emergency—an important step forward in safety.

Reductions in personnel costs also played an important role in the C-17's design. To meet wartime and contingency requirements, military airlifters must fly a large number of hours each day. To conduct sustained operations at these high utilization rates, multiple crews are required—the Military Airlift Command has attempted to maintain four crews per aircraft for C-141s, five per aircraft are planned for the C-17. Obviously, reductions in the size of the crew required to fly an aircraft can offer important savings in personnel costs. The C-17 will feature a crew of three, versus an average of six on a C-141[11] and more on a C-5. Extensive design and engineering attention went into ensuring that this crew of three would be able to smoothly perform all necessary tasks. Not only does this save money, but in combat operations, it places fewer U.S. personnel at risk. For example, four C-130s are required to deliver approximately the same amount of cargo as a single C-17. Just three crewmembers would be placed at risk using the C-17 versus 20 or more for the C-130s.

The work of other crew members on C-141s and C-5s is performed by on-board computers that do mission planning and operations, engine monitoring and control, and systems management. The four Cathode Ray Tubes (CRTs) and two Head Up Displays (HUDs) allow the two person flight crew to conduct all aspects of the airlift mission safely and effectively. The cargo compartment has been optimized to permit safe and efficient operation with one loadmaster for any mission.

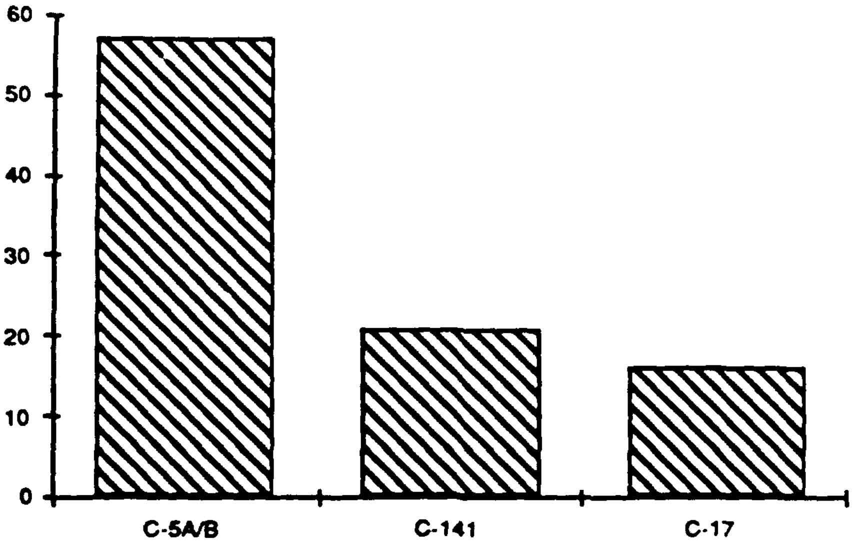

Figure 7—Maintenance Man Hours Per Flight Hour

[11] A basic C-141 crew can consist of five, but many missions require more than one loadmaster. Additionally, some—primarily airdrop—require a navigator.

Personnel costs are also reduced through substantial reductions in the number of maintenance man-hours per flying hour (see Figure 7, previous page). Significant improvements in avionics and reliability and maintainability features make such reductions possible.

These warranted reliability and maintainability features were designed into the aircraft from the start. Simplicity was a key feature in the design process. For example, the landing gear features only 29 major components, compared to 145 in the C-5. Extensive use of proven technologies and "off-the-shelf" components aids in ensuring component reliability. Over half the access to maintenance areas is provided through hinged and latched doors that were sized by human engineering considerations. And almost half of these are accessible without the need for workstands. Flight controls and other equipment in the upper portions of the tail are accessible through an internal tunnel built into the tail. Engine cowlings hinge at the pylon to provide maintenance crews with enhanced physical and visual access to servicing points. A rail mounted under-floor creeper is provided to ease corrosion inspections in the under-floor area. Electronics and avionics equipment are stored in racks that are accessible from both sides and located close to the maintenance monitor panel. These reliability and maintainability efforts work together with other design features to create maximum airlift capabilities at the lowest possible cost.

The Program and the Warranties

As they should, major defense acquisition programs like the C-17 receive close scrutiny as they progress through the development cycle. Development delays and schedule slips cause concern—and in the case of the C-17 became the subject of some criticism when the first flight was rescheduled from August 1990 to June 1991. There have been some genuine problems in C-17 development, and while this is not uncommon in programs of this scale, they are certainly not desirable and demand increased attention and action. On the other hand, a clear difference should be made between the concerns which are real, and those, many of which have been aired in the media, which are based on inaccuracies and exaggerations.

As a result of aggressive corrective action by the contractor and Air Force program managers, the program (including avionics—which played a major role in the schedule slip) is back on track. Electronic flight controls and the mission computer as well as avionics integration testing and validation are progressing well on the schedule to first flight. Assembly of the first aircraft, with the commercially certified Pratt and Whitney engines installed, was completed in December 1990. Systems testing is on track. Flight and laboratory test organizations and plans are in place to support extensive air and ground testing. In short, all major milestones developed since the re-baselining of the program in November 1989 have been met on the schedule for first flight by June 1991. While in a development program of this magnitude there will likely continue to be challenges to overcome, the Air Force has confidence in the C-17.

Historically, when the Department of Defense has put a new weapon system into the inventory, it has had no way to be sure that the system would achieve designed reliability, maintainability, and availability (RM&A). The C-17 contractor warrants 30 separate C-17 warranty categories, including RM&A and aircraft structural and spares conformance. The C-17 is the first major weapon system to offer a manufacturer's warranty guaranteeing that the American people will get what they've paid for.

McDonnell Douglas has warranted the mature C-17 weapon system for a 93% mission completion success probability (MCSP) rate. Although not a reliability rate tracked in the current fleet, MCSP is a contractual guarantee that the C-17 will complete its assigned mission as scheduled. Obviously, this means that McDonnell Douglas has great incentive to design in reliability and maintainability to ensure that the standard is met—but should, for some reason, reliability fall below that standard, the contractor would be responsible for taking corrective action. The warranty is for 10 years/10,000 hours on airframe components and for 30,000 hours on the structure. This first-of-a-kind warranty is one more reason that the C-17 is the nation's wisest possible investment in airlift capability.

CONCLUSION

As we approach the 21st century, we'll be reshaping our military forces to fit the emerging security environment. The Air Force will do its part, tailoring our capabilities to meet the nation's needs and priorities. As highlighted in the USAF's strategic planning framework, *Global Reach—Global Power*, one of the most valuable services the Air Force will provide in this security environment is to supply rapid global mobility, enabling smaller, more centrally-based U.S. forces to operate with global reach. Recent events in the Persian Gulf have provided dramatic emphasis as to why the nation needs robust and flexible airlift capabilities for the long-term future. Airlifters, capitalizing on airpower's speed, range, and flexibility, enable the nation to reach out and deter, support, build influence, and help. To support our national strategy, the United States needs the responsive mobility provided by airlift.

The C-17 is the right airlifter for the future. The uncertainties in the emerging international security environment place a premium on flexibility. From the inception of the program, the C-17, which combines the capabilities of both a strategic and tactical airlifter in the same airframe, was designed to be the most versatile air transport in the world. The program enjoys extraordinary support not only in the Air Force, but in the Department of Defense. The C-17 will provide rapid mobility for all elements of our armed forces. Every Service Secretary—and virtually every Service Chief and unified and specified CINC—has testified to the need for this aircraft.

If all we wanted to do was extend our current airlift capabilities indefinitely, the C-17 would be the most cost-effective answer. But the C-17 offers much more. It offers significant increases in capability, and substantial reductions in life cycle costs. The investment to date in the C-17 has been significant, and the investment required is even more significant—but the return on investment in terms of national security more than justifies the expense.

Airlift is a national asset that will become of increasing importance to national security as we enter the uncertain future. It serves America's interests in peace and in crisis, as well as in war. With the range and ability to operate into virtually any airfield, the C-17 offers the responsiveness necessary to cope with fast brewing crises and the muscle to get deterring forces where they need to be. This is a capability our nation must have. The United States Air Force is fully committed to the C-17 as the means to provide global reach to America's forces and put backbone into conventional deterrence for the 21st century.

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